HYDRO-ELECTRIC INQUIRY COMMISSION

ENGINEERING DATA

THE QUEENSTON-CHIPPAWA POWER DEVELOPMENT

CHAPTER "H"—CONSTRUCTION PLANT

EARTH AND ROCK EXCAVATION
INTAKE, WELLAND RIVER, FOREBAY, POWER HOUSE AND TAILRACE

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS

Chapter H.

CONSTRUCTION PLANT

(Earth and Rock Excavation)

(Intake, Welland River, Forebay, Power House and Tail-race)

Walter J. Francis.

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Chapter H.

CONSTRUCTION PLANT

by Walter J. Francis.

Chapter H, dealing with Construction Plant, is divided into four parts, of which this is the fourth, being a description of the plant devoted to the earth and rock excavation of the Intake, the Welland River, the Forebay, the Power House and the Tail-race. The first part of Chapter H deals with the construction plant used in concrete work; the second part with the plant used in transportation, while the third part takes up the construction plant used for the earth and rock excavation of the Canal.

CONSTRUCTION PLANT FOR EARTH AND ROCK EXCAVATION

Intake, Welland River, Forebay, Power House and Tail-race.

General.

The excavation work in the Intake and in the Welland River was entirely in earth and, as carried out up to March 31st, 1922, involved methods different from those used in the earth and rock excavation of the Canal. This work was sub-aqueous excavation.

The Forebay excavation was done in the same way as the Canal excavation and in the dry, and with the same plant. The Gate-house excavation was carried out in the same way as the Forebay excavation.

The Power House excavation was also done in the dry by means of the shovels which had worked in the Canal.

The rock faces of the walls of the Forebay excavation were not lined with concrete as in the case of the Canal, but were finished with gunite over all the faces of the softer rock that had been exposed. The floor of the Forebay was left as excavated.

Gunite was applied also to the less durable portions of the trimmed surface of the cliff after the Power House, the Penstocks and the Promenade were completed. Practically no work was done on the face of the cliff except trimming and scaling by hand over those portions in the vicinity of the Power House building not occupied by the concrete envelopes of the Penstocks. The excavation for the penstock envelopes was carefully cut down by hand and light blasting.

The Intake.

The Design of the Intake.

It was originally intended to construct the Intake in the usual form of submerged boom, but in May, 1918, the engineers of the Hydro-Electric Power Commission decided to adopt a design of Intake which would in their judgment

The Horsby excavation was done in the same way as the Omni excavation and in the dry, and with the same plant. The Oke-Grove excavation was carried out in the same way as the Horsby excavation.

The Lower Dunn excavation was also done in the dry by means of the shovels which had worked in the Omni.

The rear faces of the walls of the Omni excavation were not lined with concrete as in the case of the Omni, and were finished with gunite over all the faces of the walls+ such that had been exposed. The floor of the Trading Hall is of concrete.

Utility lines supplied plan by the Idaa Hydro Electric Commission and the Dunn Hydro Electric. Practically no work was done on the face of the cliff except trimming and scaling by hand over those portions in the vicinity of the Power House Building as directed by the Resident Engineers and the Foreman. The excavation for the portion overlying was carefully set down by hand and light blasting.

The Joints.

The Joints at the Intake.

It was originally planned to construct the joints in the usual form of notched ends, but in May, 1911, the engineers of the Idaa-Electric Power Commission decided to adopt a design of joints which would be more flexible

minimize the danger of shutting down of the power plant through ice trouble, this decision being arrived at as a result of special studies and experiments. These studies do not form a part of the construction plant which is the principal subject of this Chapter, but their decision has an indirect bearing on the construction plant and it was therefore considered in order to make a further reference to the studies and experiments at this juncture. The site of the Intake at the junction of the Welland River with the Niagara River and its relation to the principal topographical features may be clearly seen by reference to the airplane view on page H-156 hereof and being Photograph No. H-81.

In the operation of the hydro-electric power plants at Niagara Falls with the submerged type of Intake, field ice in large quantities passes under the existing submerged booms. Although the inoperative periods of the plants have not been protracted, they have nevertheless been the cause of considerable anxiety and trouble especially at that of The Ontario Power Company of Niagara Falls. A radical difference between the plant of the Queenston-Chippawa Power Development and the other developments in the neighborhood of the Falls is that the water is conveyed to the plant through a water-way thirteen miles long, whereas in the older plants the power houses are relatively close to the Intake. In the older plants the total quantity of accumulated field ice is relatively small, and it can generally be disposed of within a few days by being passed through the turbines. The engineers of the Hydro-Electric Power Commission say that they fear that the long canal of the Queenston-Chippawa Power Development presents an opportunity for an ice jam which might be quite impracticable to remove, if the field ice were permitted to pass the Intake

To face page H-156

No. H-81

Photograph showing

Airplane View of Intake

and Principal Topographical Features.

Taken January 7th, 1922.

works.

In cases where a strong east wind is blowing, the field ice is driven towards the westerly shore of the Niagara River, and, as indicated in the series of six pictures, being photographs Nos. H-82 to H-87 inclusive on pages H-158, H-159, and H-160 hereof, has been at times carried a considerable distance up the Welland River, notwithstanding the fact that it was driven against the current of the stream. The artificially reversed current of the Welland River from the Niagara River to the plant would naturally tend to make this condition more acute, and the engineers of the Hydro-Electric Power Commission state that they therefore believed there was the greater reason to try to obviate the difficulty.

Having observed the phenomena illustrated in the last mentioned photographs when a thirty-mile easterly wind was blowing, and in others of a similar nature on record, and having studied the existing methods of admitting water from the bottom of the channel, they designed a series of models and installed them in the channel at the Dufferin Islands in June, 1918. Their report on the first series of tests was completed in October of that year. As a result of the tests, the whole matter was submitted to Mr. E. D. Johnson, Consulting Engineer, for his consideration, with the request that he develop a formula for the design of the entrance openings in the submerged portions. Following Mr. Johnson's reports, a second series of experiments was conducted in January, 1919, and completed in November of that year.

The models and the experiments were all made one-twentieth full size

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current of the Holland Tiver from the Hudson River to the point would

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able distance up the Holland River, notwithstanding the fact that it was

Tunnels the westerly shore of the Niagara River, and, as indicated in the

series of six pictures, being photographs Nos. K-86 to K-91 inclusive on

pages K-185, K-186, and K-100 hereof, has been at times carried a navigi-

works.

In areas where a strong east wind is blowing, the flood ice is driven

COPY

To face page H-158

No. H-82

Photograph showing

Niagara River Drift Ice at Mouth of Welland River,

looking easterly. Strong easterly wind.

Taken April 11th, 1918.

No. H-83

Photograph showing

Niagara River Drift Ice in Welland River Channel,

looking easterly. Strong easterly wind.

Taken May 5th, 1917.

To face page H-159

No. H-84

Photograph showing

Niagara River Drift Ice in Welland River Channel,

looking easterly. Strong easterly wind.

Taken May 5th, 1917.

No. H-85

Photograph showing

Niagara River Drift Ice in Welland River Channel,

looking westerly. Strong easterly wind.

Taken May 6th, 1917.

To face page H-160

No. H-86

Photograph showing

Niagara River Drift Ice in Welland River Channel,

looking easterly. Strong easterly wind.

Taken May 5th, 1917.

No. H-87

Photograph showing

Niagara River Drift Ice in Welland River Channel,

looking easterly. Strong easterly wind.

Taken May 5th, 1917.

and the velocities were correspondingly reduced. Photographs Nos. M-88 and M-89 on page M-162 hereof show the character of the work on the models, the lower picture being that of a series of tests which indicated that it was impossible to obtain the desired results by single openings at the outer ends of the admission tubes. The upper picture shows the model tubes which were devised and which proved that it was possible to so design the admission openings throughout the length of the tube that the water could be received from the bottom of the stream in equal volume per unit of length of tube.

The decision finally adopted by the Commission was to design the Intake in such a way that the desired results would be obtained as shown by the experiments, but to obviate immediate capital expenditure it was decided that the outer part of the tubes should not be constructed until the need therefor will have been proven by the operation of the plant. Meanwhile the design stands essentially as a submerged boom intake with provision for the addition of the outer part of the tubes should such addition be found necessary.

Excavation Methods.

The method used for the excavation of the site of the Intake, located on the southerly side of Hog Island, was carried out by the dipper dredge "Charles Boone". The material above water consisted entirely of earth. The sub-aqueous portion of the site was covered by about 12 feet of water, and the rock surface carried an over-burden of about 15 feet of boulder clay

WALTER J. FRANCIS & COMPANY

COPY FOR ENCLOSURE TO Mr. J. Allan Ross.

COPY

To face page H-162

No. H-88

Photograph showing

Model for Intake Tubes at Dufferin Islands,

side openings.

Taken August 6th, 1919.

No. H-89

Photograph showing

Model for Intake Tubes at Dufferin Islands,

end openings only.

Taken September 18th, 1919.

which increased in density and hardness near the rock surface. In order to provide a dry site for the subsequent erection of the concrete Intake structure, a temporary dam was built from the north-easterly side of Hog Island outside the line of the structure and joining with the westerly shore of the River. The dam was built by driving a line of steel sheet piling down the centre of the caisson location, and depositing the earth spoil from the dredging on either side of the sheet piling. For part of the length of the dam a double row of steel piling was driven. The construction of the dam may be seen by reference to Photographs Nos. N-90 and N-91, included as page N-164 hereof. The greater portion of the spoil from the Intake site was deposited in the Niagara River immediately downstream from Hog Island in the disposal area marked "C" on the plan included herewith as page N-165. From this source the disposal area "C" received 752,093 cubic yards of material. The spoil was transported from the excavating plant to its destination in bottom-dumping scows. In the early part of the work, the scows were dumped in the channel on the northerly side of Hog Island. At the later period they used the disposal area "C", being controlled in their course by a 2,000-foot cable anchored to a pier specially built in the river and operated by a Lidgerwood unloader as a safety precaution and for speedy manipulation, the current in the river being such that it was not feasible to handle the scows with tugs.

A portion of the spoil was taken to the disposal area marked "A" on the plan already referred to, in bottom-dumping scows towed in the usual way by tugs. Two photographs, being No. N-92 and No. N-93, on page N-167 hereof, show the dredge "Charles Boone" in operation.

show the dredge "Charles Boone" in operation.

To face page H-164

No. H-90

Photograph showing

Temporary Dam Construction at Intake.

Taken June 15th, 1921.

No. H-91

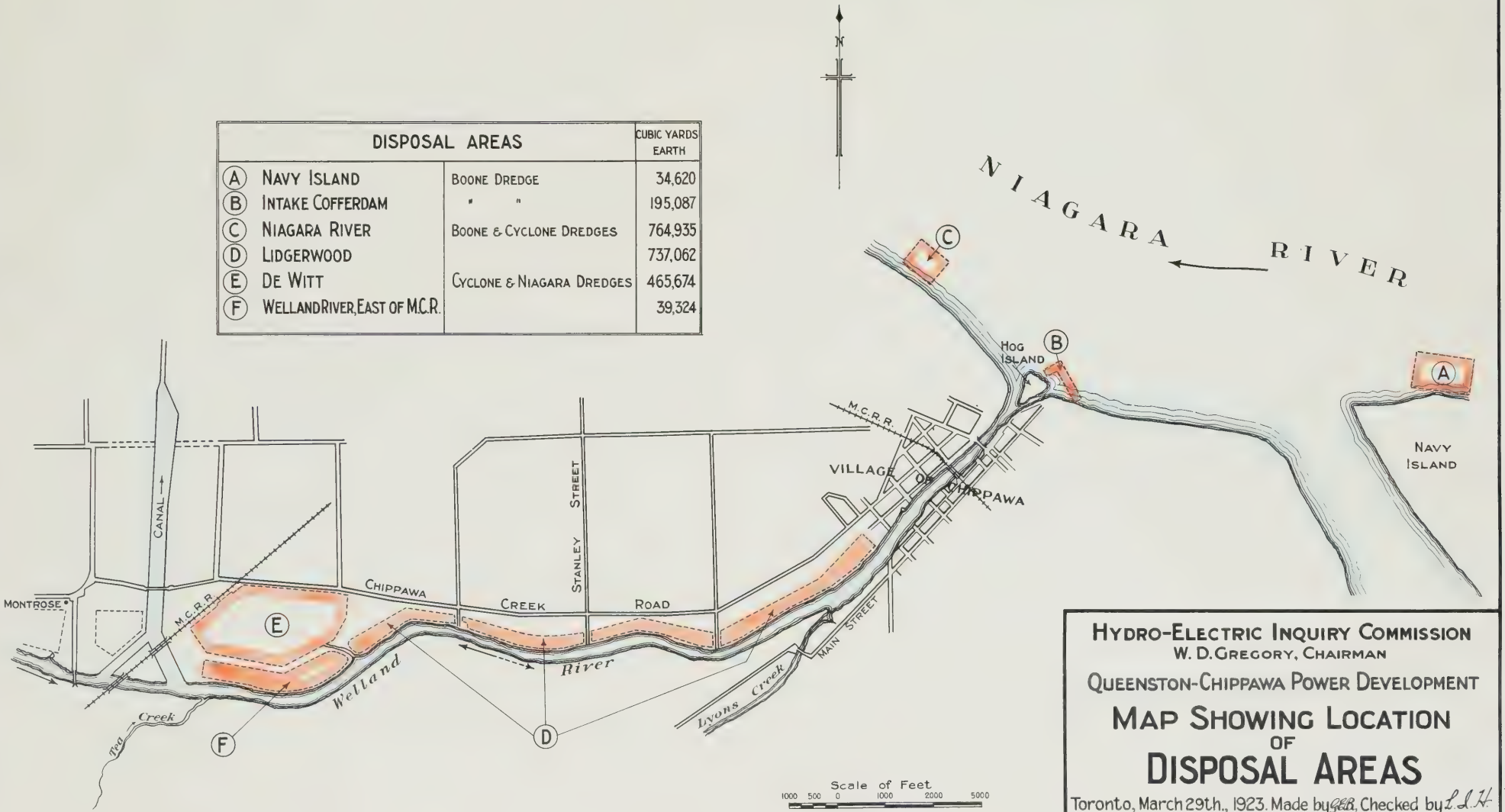
Photograph showing

Temporary Dam Construction and Dredging

at Intake.

Taken December 2nd, 1920.

DISPOSAL AREAS			CUBIC YARDS EARTH
(A)	Navy Island	Boone Dredge	34,620
(B)	Intake Cofferdam	" "	195,087
(C)	Niagara River	Boone & Cyclone Dredges	764,935
(D)	Lidgerwood		737,062
(E)	De Witt	Cyclone & Niagara Dredges	465,674
(F)	Welland River, East of M.C.R.		39,324



HYDRO-ELECTRIC INQUIRY COMMISSION
W. D. GREGORY, CHAIRMAN

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

MAP SHOWING LOCATION OF DISPOSAL AREAS

Toronto, March 29th., 1923. Made by G.E.R. Checked by L.L.H.

WALTER J. FRANCIS & COMPANY
CONSULTING ENGINEERS

(H-165)

The dredge "Charles Boone" had a dipper capacity of 5 cubic yards and was steam driven. The dredging plant consisted of the dredge "Charles Boone", the tug "Crawford", the tug "Harold B. Phillips" and four scows, one of which was used for coaling. The plant was the property of the C. S. Boone Dredging and Construction Co. Limited, of Toronto, and was rented by the Hydro-Electric Power Commission at the rate of $145.00 per day complete, under a contract duly entered into on September 18th, 1918. By the terms of the contract the plant was to be returned to Port Dalhousie by the 31st of October, 1919. It was further provided that if the contemplated work were incomplete by that date the contract time could be extended and the cancellation date of the lease could be fixed by either party on thirty days' written notice. While the plant was in transit between Toronto and Port Dalhousie the rental to be paid was $72.50 per day, being one-half the working rental.

A temporary dam was thrown across the southerly channel from Hog Island to the mainland almost opposite the lighthouse, thus enclosing the Intake site, in order to permit the water level within the enclosure to be lowered after the dredge finished. An opening was left in this dam until the work of the "Charles Boone" was completed. The dam was then closed, and the site was unwatered by means of centrifugal pumps mounted on a scow. The rock surface and the material overlying it was subsequently cleaned up in the dry by small steam shovels. The airplane picture on page E-156 shows the two temporary dams in their relation to the work.

The work of clearing off the rock on the site of the Intake was completed in 1921, and on May 5th, 1922, a contract was let to Messrs. Tomlinson,

To face page H-167

No. H-92

Photograph showing

Dredge "Charles Boone" Working in Intake.

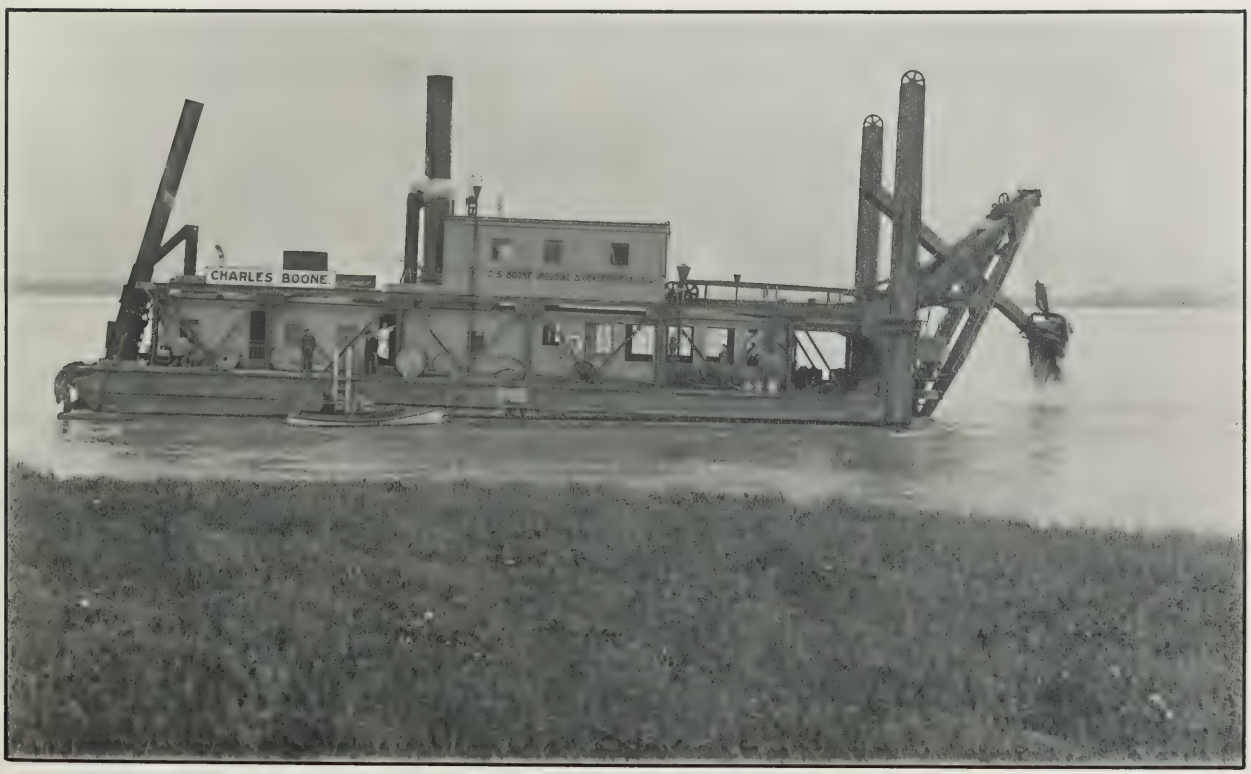
Taken October 5th, 1918.

No. H-93

Photograph showing

Dredge "Charles Boone" Working in Intake.

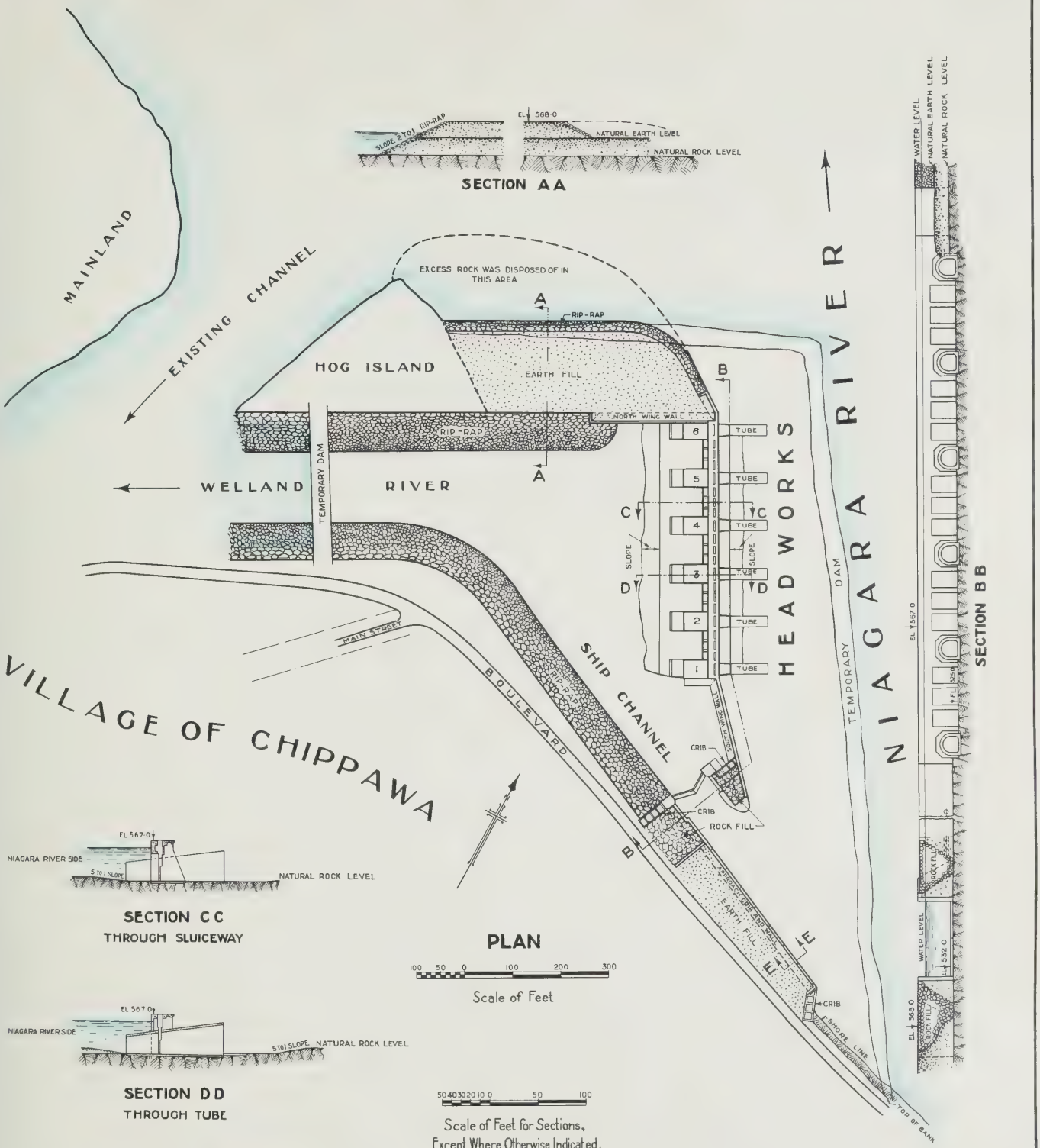
Taken September 18th, 1918.


CHARLES BOONE

Macaw and Macdonald for the building of the concrete structure of the Intake. The contractors provided their own construction plant and executed the contract under the general direction and approval of the engineers of the Hydro-Electric Power Commission. The Hydro-Electric Power Commission had no right of ownership in the construction plant used by the contractors, the contract being in the usual form in which the contractor undertakes the completion at certain definite rates of payment for specified units of finished work.

The structure included in the Tomlinson, Macaw and Macdonald contract is indicated on the plan on page M-169 hereof. The contract included also the removal of the steel sheet piling in the two temporary dams, the whole to be completed by December 1st, 1932. The contractors finished all of the work, with the exception of the removal of the piling, practically on time. The removal of the piling was completed in March, 1933.

The Hydro-Electric Power Commission arranged for the removal of the earthwork of the temporary dams by the dredge "Charles Boone", which had been previously rented for work near the Intake and in the Welland River, from the C. W. Boone Dredging and Construction Co. In the case of this particular piece of work, the C. W. Boone Dredging and Construction Co. is doing the necessary excavation at the rate of 35 cents per cubic yard for a limited amount of winter work, and 45 cents per cubic yard for the bulk of the yardage to be removed during the coming summer.



HYDRO-ELECTRIC INQUIRY COMMISSION

W. D. GREGORY, CHAIRMAN

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

GENERAL PLAN OF INTAKE

Toronto, March 29th., 1923. Made by ~~E.V.D.~~, Checked by [illegible]

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS

The Welland River.

General.

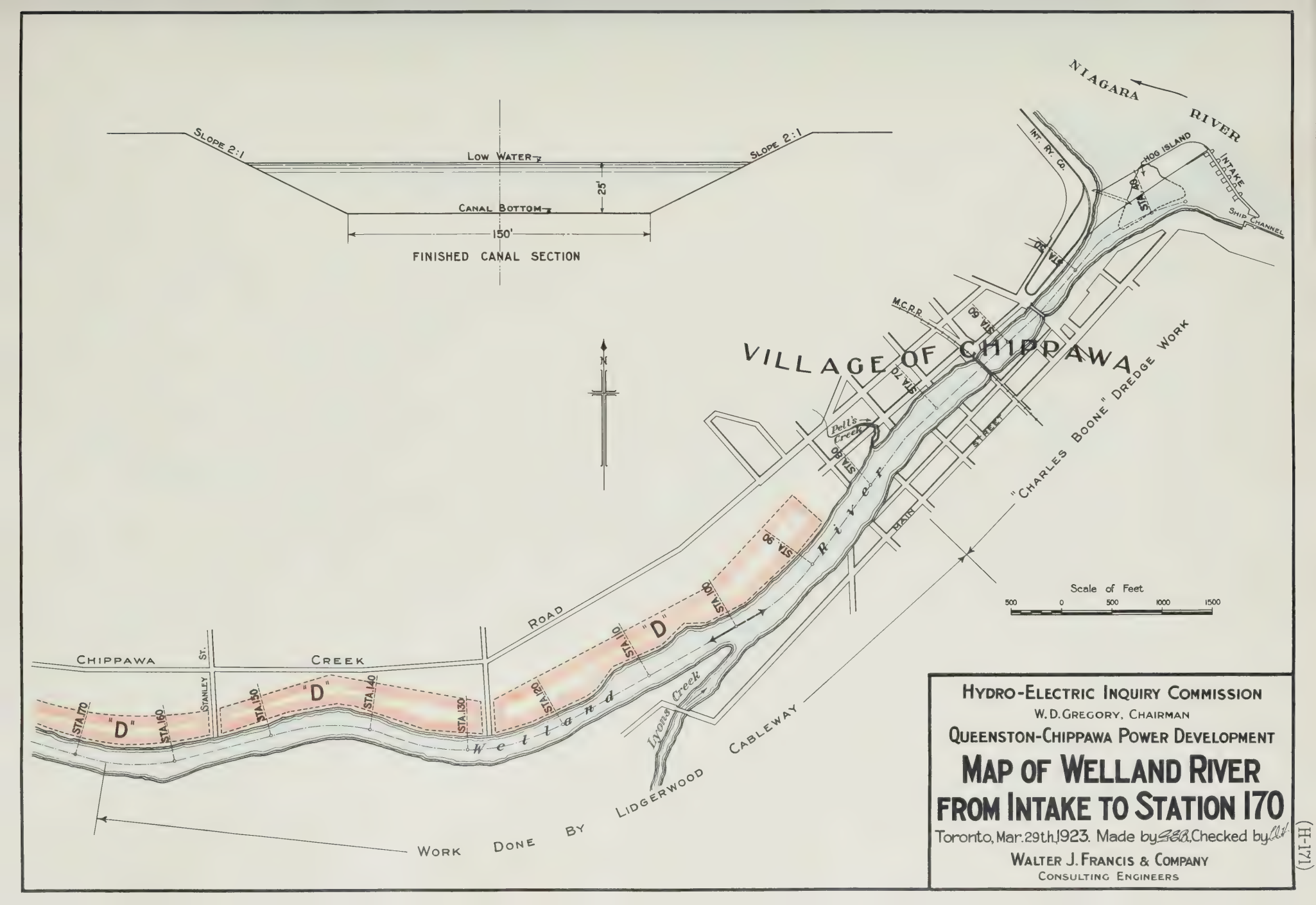
The excavation work on the Welland River up to March 31st, 1922, was all sub-aqueous, and was done by the dipper dredge "Charles Boone", the suction dredge "Cyclone", the suction dredge "Hennessy", formerly called the "Niagara", and a Lidgerwood cableway.

The Welland River from the Intake to Station 170 is shown on the map included herewith as page H-171, and that portion from Station 170 to Montrose is shown on the next map on page H-172 hereof.

The channel for its full improved section from the site of the Intake down to the Chippawa highway bridge at Station 55+50 was completed by the "Charles Boone". Between the Chippawa highway bridge and the Michigan Central Railroad bridge at Station 63+50, the channel was partly finished by the "Charles Boone". Beyond the Michigan Central Railroad bridge as far as Pell's Creek the "Charles Boone" made a pilot cut for the passage of the dredge "Cyclone" during the journey of the latter to work at Montrose on the Canal.

The greater part of the spoil from the "Charles Boone" in doing this part of the work was deposited in disposal area "C" shown on page H-165 hereof, although a small part of it was deposited by side casting.

All the work done by the "Charles Boone" was under the dredge plant rental contract already referred to on page H-166.



HYDRO-ELECTRIC INQUIRY COMMISSION

W. D. GREGORY, CHAIRMAN

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

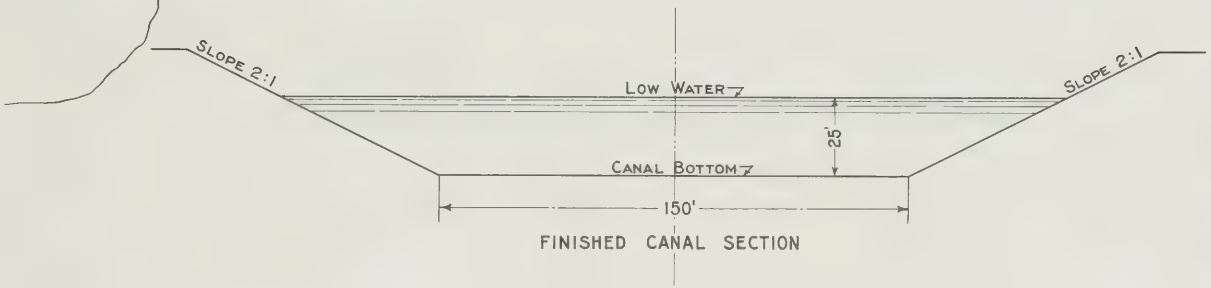
MAP OF WELLAND RIVER FROM INTAKE TO STATION 170

Toronto, Mar. 29th, 1923. Made by S.E.A. Checked by W.J.F.

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS

(H-171)



HYDRO-ELECTRIC INQUIRY COMMISSION

W. D. GREGORY, CHAIRMAN

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

MAP OF WELLAND RIVER FROM STATION 170 TO MONTROSE

Toronto. Mar. 29th., 1923. Made by S.E.B., Checked by [illegible]

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS

(H-172)

The Lidgerwood cableway used by the Hydro-Electric Power Commission for the excavation of the channel of the Welland River, commenced work at Station 73+00 on May 13th, 1918 and completed its work on July 2nd, 1921. It was purchased by the Commission for the work. The plant consisted primarily of a steel cableway suspended from two travelling towers, one on either bank of the river. The slack of the cable was taken up by counterweights suspended over the towers. The details will be seen by reference to the four photographs, Nos. H-94 to H-97, inclusive, on pages H-174 and H-175 hereof. The Lidgerwood plant was adopted by the engineers of the Hydro-Electric Power Commission as the most expeditious and economical available means of improving the Welland River channel after inspecting similar plants in the United States. The reasons for the adoption of the plant have been fully set forth in Chapter G, pages G-7 and G-8. The engineers of the Hydro-Electric Power Commission state that the work was suspended in 1921 because they considered that the immediately essential channel improvements had then been finished and that the completion of the balance of the channel improvement might well be deferred pending a drop in labour and material costs.

The cableway deposited its spoil on the relatively narrow area abutting on the northerly shore of the Welland River, marked "D" on the plan included herewith as page H-165.

The steel cable was 2½ inches in diameter, and the span between the towers was 800 feet. The excavating bucket was of the clam-shell type clearly shown in Photograph H-96 on page H-175 hereof, with a capacity of 3 cubic yards, and was worked by electric motors located in the head tower.

The Lightwood subsidy used by the Hydro-Electric Power Commission for the excavation of the channel of the Welland River, commenced work at daylight 7h+00 on May 18th, 1918 and completed its work on July 2nd, 19h1. It was pursuaned by the Commission for two reasons. The plant nomination priority of a steel cableway suspended from two travelling towers, one on either bank of the river. The slack of the cable was taken up by counterweights suspended over the towers. The details will be seen by reference to the four photographs, Nos. 34-44 to H-37, inclusive, on pages 2-174 and H-175 hereof. The Lightwood plant was adopted by the engineers of the Hydro-Electric Power Commission as the most expeditious and economical available means of improving the Welland River channel after inspecting [illegible]

for the adoption of the plant have been fully set forth in Chapter 6, pages 6-7 and 6-8. The engineers of the Hydro-Electric Power Commission stress that the work was urgent in [illegible] [illegible] that its speedy completion was essential [illegible] and that the completion of the bulkhead of the dismantl improvement might well be deferred pending a drop in labour and material costs.

The control depended the depth on the particular volume [illegible] on the northerly shore of the Welland River, marked "D" on the plan inserted [illegible] at page 2-174.

The steel mills was 8½ inches in diameter and the [illegible] tower was 800 feet. The excavating bucket was of the clam-shell type clearly shown in Photograph H-34 on page 2-174 hereof, with a capacity of 1 cubic yards, and was worked by electric motive control in the [illegible] tower.

To face page H-174

No. H-94

Photograph showing

Lidgerwood Cableway at Work in Welland River

at Station 75.

Taken May 20th, 1918.

No. H-95

Photograph showing

Lidgerwood Cableway, and Disposal Area on Westerly

Bank of Welland River.

Taken August 8th, 1918.

To face page H-175

No. H-96

Photograph showing

Lidgerwood Cableway Clam-shell Bucket Closed.

Taken May 20th, 1918.

COPY

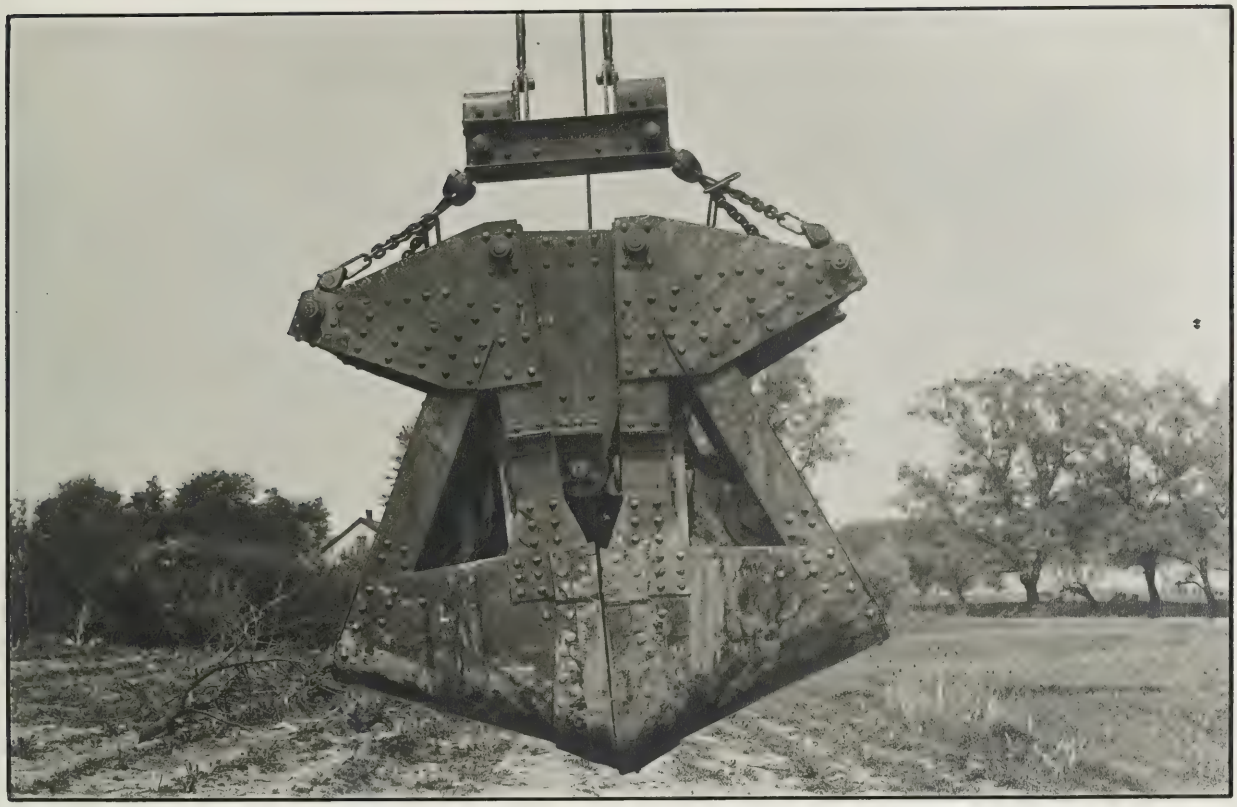
No. H-97

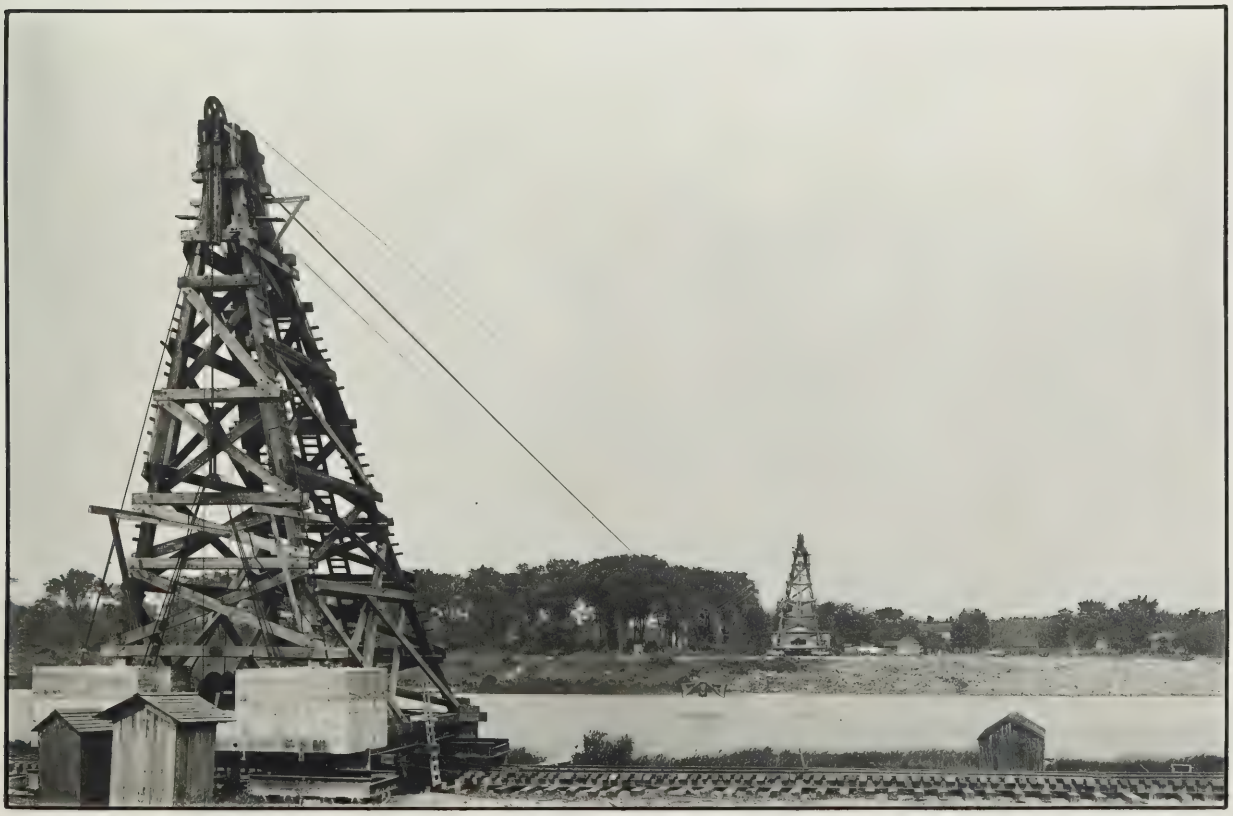
Photograph showing

Lidgerwood Cableway showing Complete Plant

at Work in Welland River.

Taken August 8th, 1918.





The total amount of material excavated by the Lidgerwood cableway was 737,062 cubic yards.

The head tower of the cableway was destroyed by fire on September 25th, 1921, as the indirect result of a storm which caused a short circuit and permitted a stray electric current to enter the operating room over the telephone wires and ignite the woodwork.

The dredge "Hennessy", a suction dredge with a 14-inch discharge pipe, was used by the Commission to do a small amount of work under contract, more particularly in connection with the removal of the last 30,000 cubic yards of sub-aqueous excavation in the earth section previous to filling the canal.

The "Hennessy" was later used by Messrs. E. G. Leahy & Company, Limited, during the summer of 1922 as part of their plant to commence excavation work pending the completion of the new hydraulic dredge "Stewart".

On May 22nd, 1922, a contract was entered into between the Hydro-Electric Power Commission and Messrs. E. G. Leahy & Company, Limited, of Ottawa, for dredging in the Welland River, whereby the contractor undertook to remove not less than 800,000 cubic yards of earth by the 31st day of December, 1922. Victory Bonds to the amount of $100,000 were deposited with the Hydro-Electric Power Commission by the contractor as a guarantee for the fulfilment of the contract. By the terms of the contract the contractor agreed that the contract prices include the furnishing of all labour and materials and the providing of all plant and apparatus required in the work. The contractor undertook also to supply all work and material in connection with the drainage of

The total amount of material excavated by the lithotomy operation was 750,000 cubic yards.

The head tower of the quarry was destroyed by fire on September 20th, 1921, as the indirect result of a storm which caused a short circuit and ignited a very flammable material in which the quarrying crews were then engaged [illegible].

The dredge "Hennessy", a suction dredge with a 14-inch discharge pipe, was used by the Contractors to do a small amount of work [illegible], particularly in connection with the removal of the last 30,000 cubic yards of non-common excavation [illegible].

The "Hennessy" was later used by Messrs. E. O. Leahy & Company, [illegible], during the course of [illegible] pending the completion of the new Wabanello dredge "Clement".

On May 22nd, 1921, a contract was entered into between the [illegible] Power Construction and Supply Co. Ltd. & Company, limited, of [illegible], [illegible] to the Pelican River, whereby the Contractor undertook to [illegible] less than [illegible] cubic yards on the 31st day of January, 1923. [illegible] Ninety Cents to the amount of [illegible] were completed with the [illegible] Power Construction by the Contractor to a point [illegible] the [illegible] excavator. By the terms of the contract the contractor agreed that [illegible] Court Prince Construction Co. Ltd. [illegible] and materials and the [illegible] rights of all plans and operations required in the work. The contractor [illegible] have also to supply all work and material [illegible] the [illegible] of

the valley of DeWitt Creek, all being included in the price paid for dredging at the contract rate.

The contract is divided into four sections containing quantities estimated for tender purposes as follows:

Section I, Canal, Station 15 to Station 60	325,000 cu.yds.
Section II, River section, Station 168 to Station 244+40.	500,000 cu.yds.
Section III, Canal, Station 0+00 to Station 15+00	175,000 cu.yds.
Section IV, Welland River, Station 244+00 to the entrance to the false or temporary channel and false channel to Station 15, canal chainage	not estimated.

The prices in the contract are:

Earth excavation	33¢ per cu.yd.
Earth excavation, in case contract be cancelled when excavation has exceeded 500,000 cubic yards but has not reached 800,000	35¢ per cu.yd.
Earth excavation in quantities less than 500,000 cu.yds..	40¢ per cu.yd.

For the completion of the contract Messrs. Leahy & Co. built a specially designed electric suction dredge, the "Stewart", having a 20-inch discharge pipe, and a minimum estimated capacity of 175,000 cubic yards per month. The capacity of the motor driving the pump is equivalent to 1,500 horse-power, and the electric energy was purchased by the contractor from the Niagara System of the Hydro-Electric Power Commission.

There was considerable delay in the construction of the dredge, and it did not commence the river excavation until October 26th, 1922.

The dredge and its equipment being the property of the contractor, the Hydro-Electric Power Commission has no right of ownership therein.

System of the Hydro-Electric Power Commission.

The dredge "Stewart" was operated 94 working days during the winter season of 1922-23, but it was seriously handicapped by the severe winter weather, and the shifts per day varied greatly. During this period 327,759 cubic yards of material were removed.

The Forebay.

The excavation of the Forebay, which was entirely in rock, was carried out by the same general methods as were used in the Canal excavation, and by the same plant. This also applies to the excavation for the Screen House substructure. On the completion of the rock excavation, the walls were scaled down and treated with gunite to prevent disintegration. The floor of the Forebay was not lined with concrete, but was left, after being trimmed up, in its natural condition, the engineers of the Hydro-Electric Power Commission considering that the seams would naturally silt up through the disintegration of the shale of which there was considerable at this point and that water-tightness would be obtained within a very short period of time in event of there being infiltration through the bottom when first filled with water.

The general conditions in the Forebay may be seen by reference to Photograph No. H-98 on page H-179 hereof.

The concrete diffuser at the entrance to the Forebay was built with the ordinary construction plant employed on the work in due course, a mixing machine, a concrete tower, chutes and concrete buggies being used.

To face page H-179

No. H-98

Photograph showing

Rock Excavation at Inlet of Forebay,

looking southerly.

Taken January 8th, 1920.

Screen House, Power House and Tail-race.

The excavation for the Penstocks was all in rock and involved two distinctly different construction methods. The horizontal section of the Penstocks from the Screen House on the face of the cliff was done by tunnelling, and the inclined portion over the face of the cliff was executed by careful close drilling, light blasting and hand trimming, the spoil being removed after it had dropped to the bottom of the gorge. Generally speaking, the face of the cliff was not removed, but was merely trimmed and adapted so that it would conform to the relative positions of the Screen House and Power House and the alignment of the Penstocks. The exposed faces of the crystalline rock were left in their natural condition, and the less durable rock above the power house roof was treated with gunite to prevent disintegration.

The shaft and tunnel for the elevator at the southerly end of the Screen House was excavated by the usual methods employed for shafts and tunnels.

The Photograph, No. H-99, on page H-181 hereof shows the face of the cliff at the site of the Power House after it had been cleared of trees and vegetation. The next page, H-182, shows a picture, Photograph No. H-100, of the trimming operations in progress. Photograph No. H-101, page H-183 hereof, shows one of the channels trimmed for a main unit penstock.

The site of the Power House was entirely in rock. On the rock surface there was a considerable overburden of talus, which was removed by means of electric shovels and cast towards the river, thus assisting in forming the

To face page H-181

No. H-99

Photograph showing

Power House Site Cleared of Trees and Vegetation.

Taken May 2nd, 1918.

To face page H-182.

No. H-100

Photograph showing

Trimming Work on Face of Cliff at Power House.

Taken November 3rd, 1920.

COPY FOR ENCLOSURE TO Mr. J. Allan Ross.

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To face page H-183

No. H-101

Photograph showing

Penstock Channel Trimmed in Face of Cliff,

at Power House.

Taken June 18th, 1921.

temporary dam between the substructure excavation and the river current. This detail of the unwatering of the substructure site proved so efficient that the excavation was easily kept dry by means of one six-inch electrically driven centrifugal pump. The excavation for the substructure was done by drilling and blasting, and the spoil was loaded by shovel No. 4 (electric) into cars which were hauled out of the excavation at the commencement of the work on a 17 per cent. grade by a steam locomotive. The use of the electric shovel obviated the difficulty which would have rendered it impossible to commence the excavation with a steam shovel on the necessarily and abnormally steep cutting-in grades. This construction track joined the Queenston-Power House Railway which acted as a service railway for the disposal of the spoil in the Queenston disposal area. The excavation of the power house pit averaged about thirty feet in depth, and was almost entirely in Queenston red shale. The character of the rock formation as a whole may be seen by reference to the general cross sections at the Power House on pages H-45 and H-46 in the Chapter entitled General Description. The use of the large shovel, purchased for the Canal excavation, rendered it possible to complete the Power House substructure excavation early enough to permit the first main unit to function as soon as the Canal was ready to receive the water from Chippawa.

Photographs Nos. H-102, H-103 and H-104, included as pages H-185, H-186 and H-187 hereof, respectively, show various stages in the progress of the excavation work at the site of the Power House, and are self-explanatory.

The general bottom at Elevation 424, having been reached by the shovel

To face page H-185

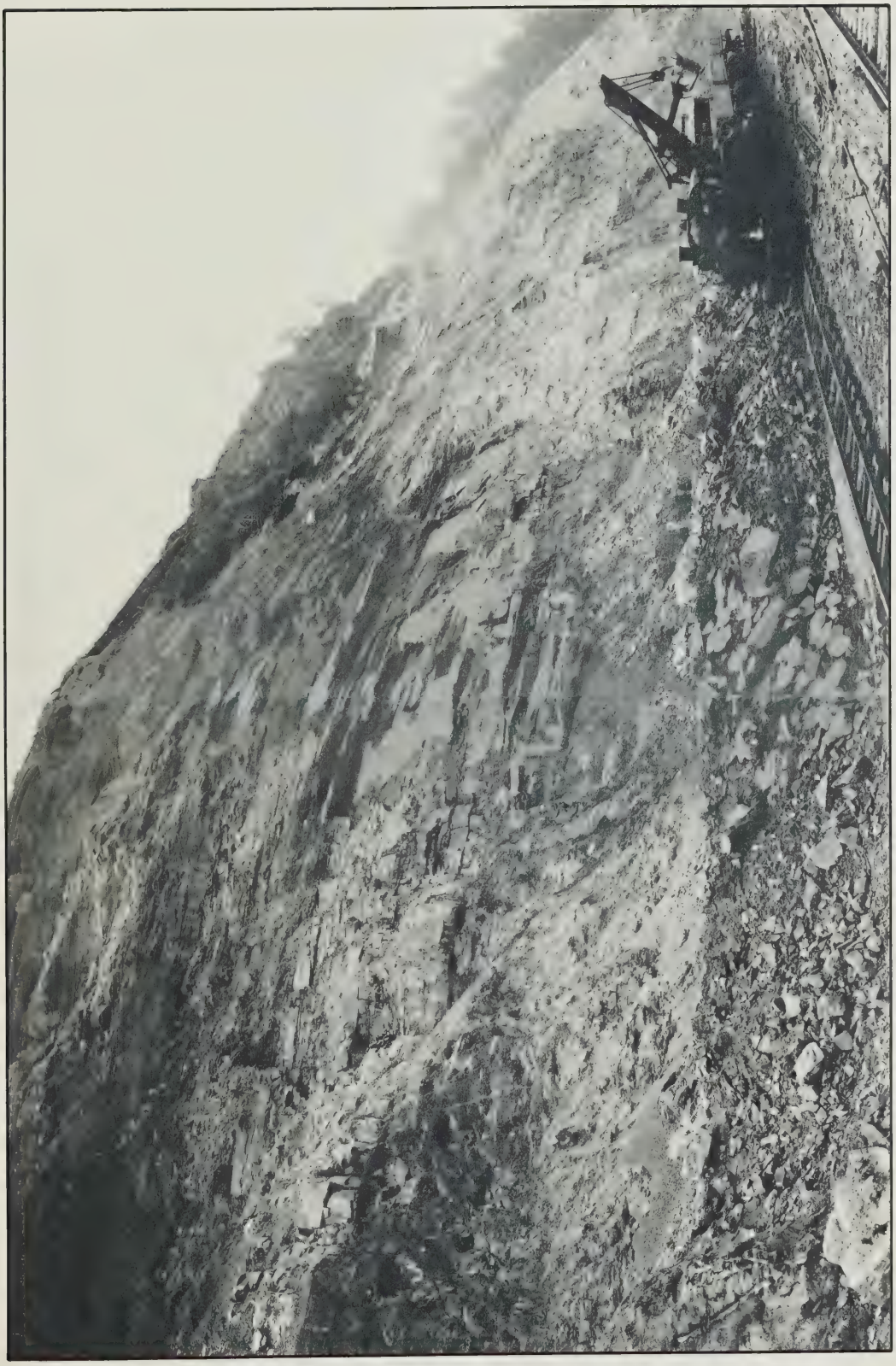
No. H-102

Photograph showing

General View of Power House Excavation.

looking northerly.

Taken August 7th, 1920.



To face page H-186

No. H-103

Photograph showing

General View of Power House Excavation,

looking northerly.

Taken March 3rd, 1920.

(H-186)

To face page K-187

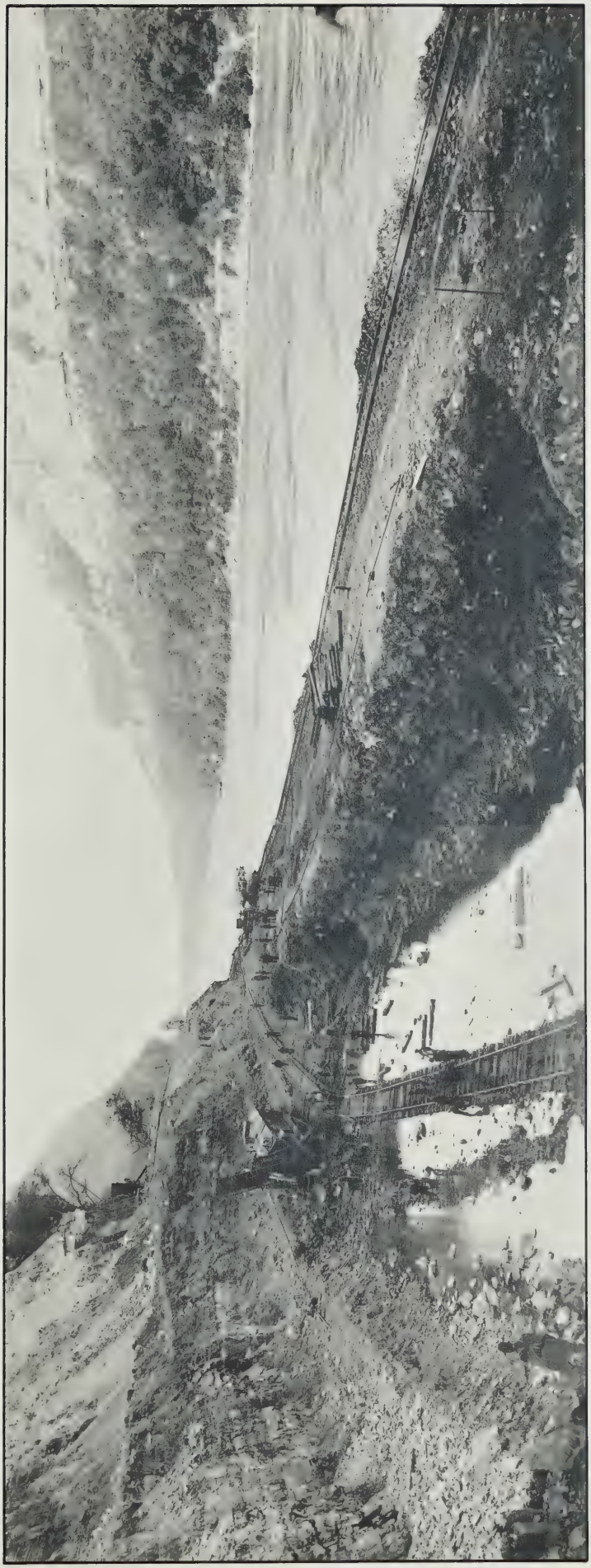
No. K-104

Photograph showing

General View of Power House Excavation,

looking northerly.

Taken October 9th, 1920.



which worked down from the northerly end, the trimming and preparation of the sides and floor in detail for the reception of the concrete was carried on, unit by unit, commencing at the southerly end. The general progressive plan of construction may be seen by reference to the photographs describing the Power House in Chapter E, pages E-60 to E-64.

The Tail-race excavation consisted mainly of removing the temporary dam along the easterly face of the Power House substructure. This dam was taken away after the turbine installation had been completed, by the use of a travelling derrick with an orange-peel bucket. The excavation was done unit by unit from the southerly end of the building, and the spoil was cast into the river.

With the exception of the excavation work done by the travelling derrick and orange-peel bucket, all the excavation of the Power House was carried out by the use of plant previously employed on the Canal. The excavating units, when released from the Canal work, were transferred by means of the Queenston-Power House Railway to the site of the Power House and there employed.

Subsequent to the completion of the installation of Unit No. 5, the excavation methods above described have been modified owing to the restricted area of operations and the proximity of the main units; consequently some of the smaller shovels formerly engaged on the upper works are now being used in the excavation for the extension of the substructure, but generally the same principles are employed.

Walter J. Francis

Consulting Engineer.

Toronto, March 27th, 1923.

with the exception of the excavation work done by the travelling derrick and crusher-pool bucket, all the excavation of the Tower Locks was carried out by the use of plant previously employed on the canal. The excavating units, when released from the Outer Locks, were transferred by means of the incomplete-tower horse railway to the site of the Tower Horse and there employed.

Subsequent to the completion of the installation of Unit No. 5, the excavation of the approaches and the proximity of the mix units; consequently none of the earlier service records relating to the tower locks are available.

Principles are explained.